Analysis of the Factors on the Radiation Safety Management of PET-CT in Medical Centers

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Introduction

The most important thing in curing cancer is early diagnosis, and it is proven that the survival rate is higher when treated at the early stage of a cancer process.

Because most diseases proceed with functional changes in physiological a nd biochemical ways before presenting anatomic changes, a method called Positron Emission Tomography-Computed Tomography(PET-CT) is aimed to effectively diagnosis these diseases was invented.

This early detection method led to drastic changes in all medical fields.

In Korea, the PET-CT was introduced in 2002, and the number has soared since then.

There is rapidly increasing numbers of demands for the PET-CT and nuclear medicines of this piece of equipment across the nation, and it is expected the installation of this piece of equipment will constantly increase.

However, the latency of the radiation exposure to patients and medical staff has increased according to significant increases in the installation and application of the PET-CT.

As human behavior is understood as a dynamic triangle model where cognitive factors or personal factors, behavioral factors and environmental factors interact with one another, behavioral aspects and environmental aspects need to be considered at the same time for the purpose of radiation safety management.

It is important to figure the aspects of radiation safety management according to the use of radiation, and direct observation is the most ideal way to figure the aspects of radiation safety management.

However, as the scope of study subject is large and it is impossible to conduct measurement in reality, questionnaire surveys are necessary to acquire information in an indirect way.

The for questionnaire' s, reliance and validity are determined by respondents and characteristics of the measuring tools, and unless they are verified, they cannot be used in the study.

Accordingly, the study aimed to develop a measuring tool with validity and reliance that can measure environmental aspects and behavior aspects influencing radiation safety management.

The development processes of the tool include a process of making questions, a process of establishing questions and a process of verifying validity and reliance.

Also, this study analyzed the factors related to radiation safety management that are basic resources to establish a radiation safety plan.

2. Methods

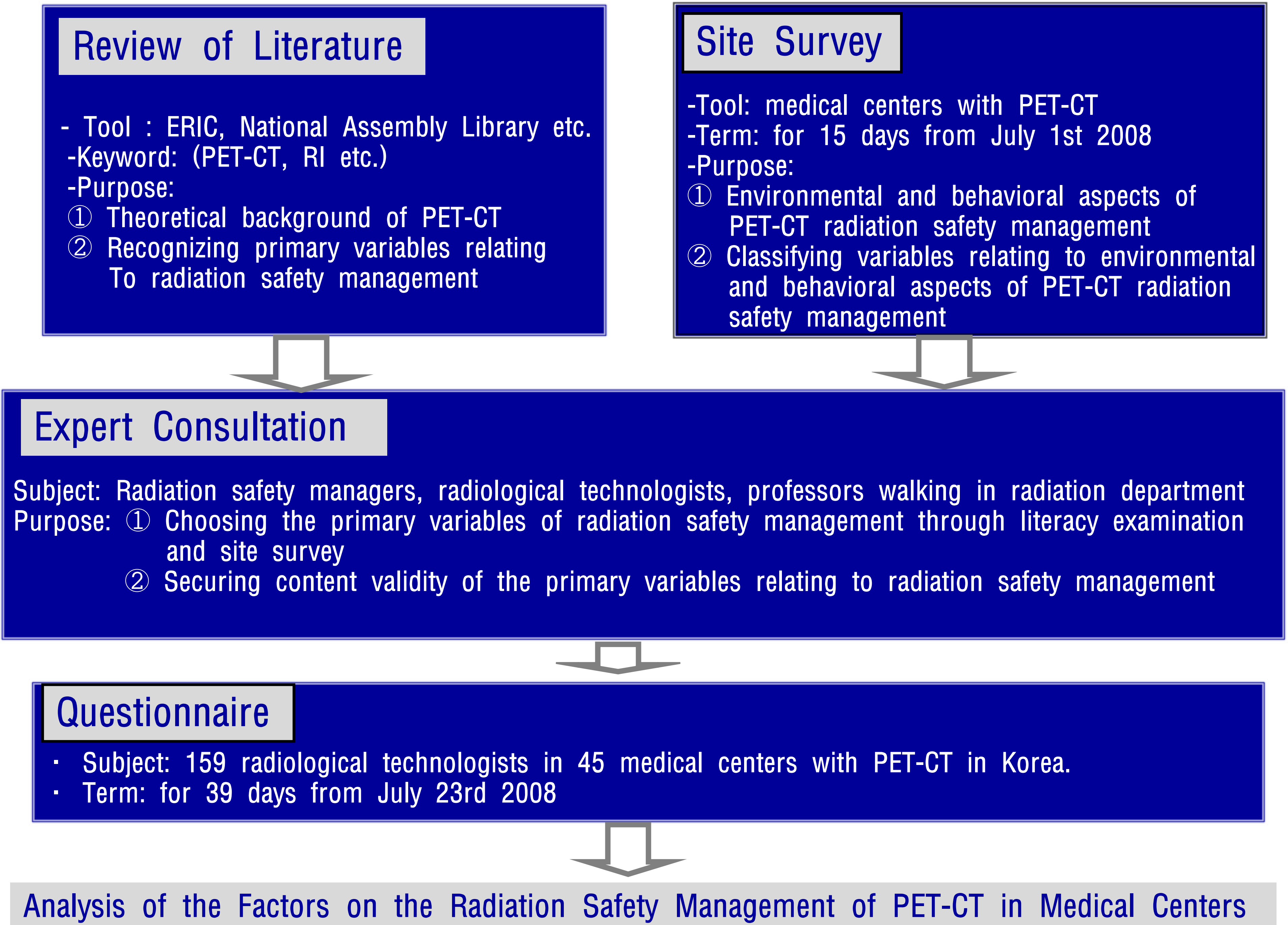
2-1. Research process

To analyze the radiation safety management factors of PET-CT, this study designated major variables affecting radiation safety management among variables found throughout the first round of site survey and review of literature.

To secure the validity of primarily designated variables affecting radiation safety management, this study consulted with radiation experts including radiation safety managers, radiological technologists, and professors working in radiology departments.

The study conducted preliminary inquiries based upon the primarily designated variables, and establish the final questionnaire through some modifications and complements.

This study surveyed 159 radiological technologists who were in charge of PET-CT through the final questionnaire and conducted the factor analysis on the PET-CT radiation safety management(Fig 1).


Review of Literature
- Tool : ERIC, National Assembly Library etc.
-Keyword: (PET-CT, RI etc.)
-Purpose:
① Theoretical background of PET-CT
② Recognizing primary variables relating To radiation safety management
Site Survey
-Tool: medical centers with PET-CT
-Term: for 15 days from July 1st 2008
-Purpose:
① Environmental and behavioral aspects of PET-CT radiation safety management
② Classifying variables relating to environmental and behavioral aspects of PET-CT radiation safety management
Expert Consultation
Subject: Radiation safety managers, radiological technologists, professors walking in radiation department
Purpose: ① Choosing the primary variables of radiation safety management through literacy examination and site survey
② Securing content validity of the primary variables relating to radiation safety management
Questionnaire
· Subject: 159 radiological technologists in 45 medical centers with PET-CT in Korea.
· Term: for 39 days from July 23rd 2008
Analysis of the Factors on the Radiation Safety Management of PET-CT in Medical Centers

2-2. Analysis methods

Review of Literature, site survey, and expert consultation were conducted as qualitative researches, through which validity-secured variables were chosen, and the final questionnaire was completed.

Questionnaire analyses were performed using the statistical package program of SPSS Win 12.0 for obtaining Cronbach´s α, Varimax, frequency, percentage, average, standard deviation, and t-test, One-way Anova, Pearson´s Correlation Analysis, and regression analysis were also applied.

Results

3-1. Behavior and environment in relation to radiation safety management through Review of Literature, site survey, and expert consultation

Finally selected questions consisted of a total of 60 questions including

25 environmental questions
6 questions on radiation safety management environment for patients
7 questions on radiation safety management for guardians
4 questions on radiation safety management environment for radiation technologists
8 questions on general items of radiation safety management environment.

35 behavioral questions
11 questions on radiation safety management behavior for patients
4 questions on radiation safety management behavior for guardians
12 questions on radiation safety management behavior for radiation technologists
8 questions on general items of radiation safety management behaviors

3-1-1. Environmental aspect relating to radiation safety management

Environmental aspect relating to radiation safety management was classified into four subclasses of patients, guardians, radiological technologists, and general items(Table 1).

Table 1.Questions on Environmental Aspect Relating to the Radiation Safety Management

Division	Subject		Contents	Confidence
Environmental aspect to reduce radiation exposure	Patients	1	Equipment to measure weight and height of patients in the Prep room	0.687
		2	Posting a notice relating to PET-CT examination for patients in radiation management area	
		3	Installing toilets for quarantined patients	
		4	Installing in quarantine to protect other patients from exposing to radiation	
		5	Posting notices of quarantined areas	
		6	Installing surveillance cameras in quarantine to observe patients' behaviors	

Guardians	1	Install shielding doors and walls in RI distribution room	0.728
	2	Preparing guidebooks for guardians	
	3	Shielding waiting rooms for guardians against distribution or in quarantine	
	4	Preparing protective equipment for guardians	
	5	Taking radiation protective measures in RI distribution and in quarantine, PET-CT examination rooms for the public	
	6	Setting structures in quarantine not to allow the public to get access to the room	
	7	Install shielding doors and walls in quarantine	
Radiological technologists	1	Radiological technologists preparing dosimeters themselves	0.626
	2	Preparing protective equipment such as protective gloves, protective glasses, aprons and lead sealing cylinder in RI distribution rooms	
	3	Installing alarms to notify the technologists of excess of permissible level of radiation	
	4	Installing intra-communication device with rooms in quarantine	

General items	1	Preparing Survey meter to measure radiation amount and the level of radiation contamination in RI distribution facility, quarantine areas and PET-CT examination rooms	0.813
	2	Preparing decontamination device in RI distribution facility, quarantine areas, PET-CT examination rooms	
	3	Preparing temporary depository made of lead shield	
	4	Covering walls and doors in RI distribution facility, quarantine areas and PET-CT examination rooms	
	5	Preparing ventilation facilities in RI distribution rooms according to related regulations	
	6	On the entrance of RI distribution rooms, quarantine areas, PET-CT examination rooms, put radiation mark	
	7	Installing hood, glove box in RI distribution rooms	
	8	Preparing books for record of radiation amount (radioactivity)	

3-1-2. Behavioral aspect of radiation safety management

Behavioral aspect of radiation safety management was classified into the 4 subclasses of for patients, guardians, radiation technologists and General items(Table 2).

Table 2.Question on Behavioral Aspect Relating to Radiation Safety Management

Division	Subject		Contents	Confidence
Behavioral aspect to reduce radiation exposure	Patients	1	Ensure patients have fasted and check blood-sugar levels before RI injection	0.920
		2	Measuring patients' physical examination such as weight and heigh t	
		3	Explaining cautions in RI distribution and stability rooms to patients	
		4	Recommending the use of exclusive bath room to patients after RI injection	
		5	Measuring the amount and term of injection to before and after RI injection to patients	
		6	Changing fomes in stability room	
		7	Checking whether patients have urinated or not before examination	
		8	Advising patients not to drop urine on their outfits	
		9	Checking patients for not having metal things(keys etc.)with them	
		10	Advising patients not to move during examination	
		11	Notifying patients of cautions after the examination such as drinking sufficient water and not contacting pregnant women and babies	

Behavioral aspect to reduce radiation exposure	Guardians	1	Maintaining the distance between guardians and patients	0.655
		2	Distributing RI while closing the door for the safety of the public	
		3	Explaining cautions about radiation exposure to guardians	
		4	Providing protective equipment to guardians during examination in which the help from guardians is requisite	
	Radiological technologist	1	Checking RI container for opening or closing after RI distribution	0.868
		2	Using lead sealing cylinder in RI injection	
		3	Trying to reduce the period of meeting with patients after RI injection	
		4	Using protective equipment such as protective gloves, protective glasses, aprons and lead sealing cylinder in RI distribution	
		5	After using RI, measuring contamination of radiation work Technologists and, if necessary, decontaminating	
		6	Wearing personal dosimeter in radiation work	
		7	Checking if doors of examination rooms are open or not	
		8	Conducting regular education training for radiation work technologists	
		9	Medical check-ups for radiation work technologists	
		10	Checking radiation work technologists for the amount of radiation exposure quarterly	
		11	Wearing protective equipment when entering radiation management area	
		12	Implementing various designated regulations and process regarding safety management regulations when conducting radiation work	

Behavioral aspect to reduce radiation exposure	General Items	1	Measuring the level of contamination on lead sealing cylinder used for RI injection with survey meter	0.771
		2	Examining and mending equipment to exactly measure the amount of RI radiation	
		3	Managing the record of use, deposit and disposal of RI	
		4	Measuring the level of radiation and contamination of equipment and device used in radiation work	
		5	Depositing used RI injectors in temporary depository	
		6	Measuring the amount of radiation of temporary depository and disposing them quarterly	
		7	Assorting radiation wastes such as vials, injectors, needles and cotton balls generated by RI distribution	
		8	Managing the status of PET-CT	

3-2. Questionnaire

3-2-1. Personal, environmental, and behavioral aspects

Self-efficacy value of the personal aspect was 81.53.

As for the environmental aspect value of radiation safety management, that for general was 86.87, that for patients was 85.83, that for guardians was 75.79, and that for radiological technologists was 75.35.

As for the behavioral aspect value of radiation safety management, that for patients was 91.78 value, that for radiation technologists was 84.85, that for general was 84.22, and that for guardians was 72.78.

As for the level of radiation safety management, the environmental aspect value was 80.96, and the behavioral aspect value was 83.43.

Table 3. Personal, environmental, and behavioral Aspect Relating to Radiation Safety Management

Characteristics	Item	Min. Value	Max. Value	mean±SD
Personal aspect	Self-efficacy	46	100	81.53±10.986
Environmental aspect	Patient	0	100	85.83±14.655
	Guardian	36	100	75.79±16.567
	Radiological Technologist	25	100	75.35±15.964
	General item	50	100	86.87±12.568
	Total	49	100	80.96±11.465
Behavioral aspect	Patient	48	100	91.78±11.779
	Guardian	25	100	72.78±18.160
	Radiological Technologist	46	100	84.85±13.103
	General item	47	100	84.22±12.648
	Total	49	100	83.43±11.842

3-2-2. Differences in the environmental aspect of radiation safety Management according to its general features

Private organizations were better equipped with radiation safety management environment to reduce radiation exposure than national organizations, and also the difference was significant statistically($p<0.05$)

Table 4. Differences in the environmental Aspect of Radiation Safety Management According to its General Features

Characteristics	Item		mean±SD	t or F
Regions of the organization	Patient	Capital area	84.32±15.873	0.865
		Chungcheong area	90.63±13.684	
		Yeongnam area	87.76±12.818	
		Honam area	85.71±13.248	
	Guardian	Capital area	74.00±17.260	3.374*
		Chungcheong area	83.93±12.372	
		Yeongnam area	74.38±16.161	
		Honam area	86.99±9.665	
	Radiological Technologist	Capital area	76.43±16.442	3.616*
		Chungcheong area	82.03±19.027	
		Yeongnam area	70.05±13.334	
		Honam area	83.04±15.197	

$p<0.05$

Regions of the organization	General item	Capital area	87.48±12.801	1.871
		Chungcheong area	88.67±13.768	
		Yeongnam area	83.92±12.129	
		Honam area	92.19±10.526	
	Total of the Environmental aspect	Capital area	80.56±11.869	2.424
		Chungcheong area	86.31±12.719	
		Yeongnam area	79.03±10.482	
		Honam area	86.98±9.498	

$^{*}p<0.05$

Principal of the organization	Patient	Private	86.35±14.682	0.846
		National	83.95±14.620	
	Guardian	Private	76.63±16.646	1.195
		National	72.79±16.165	
	Radiological Technologist	Private	76.88±14.671	2.300*
		National	69.85±19.185	
	General item	Private	87.23±12.427	0.680
		National	85.57±13.169	
	Total of the environmental aspect	Private	81.77±11.172	1.688
		National	78.04±12.186	

*$p<0.05$

3-2-3. Differences in the behavioral aspect of radiation safety Management according to the employment status

There were no significant differences in values through dosimeter-wearing times (TLD, FB), daily working times in the radiation management areas, numbers of daily PET-CT examinees, types of employment, and the amount of education on radiation damage protection among employment status.

Table 5. Differences in the Behavioral Aspect of Radiation Safety Management According to the Employment Status

Characteristics	Item		mean±SD	t or F
Career on PET-CT work	Patient	Less than 1 year	93.80±9.529	4.102*
		Less than 1 ~ 3 years	92.76±9.618	
		More than 3 years	86.20±17.873	
	Guardian	Less than 1 year	71.02±20.481	2.616
		Less than 1 ~ 3 years	75.27±16.664	
		More than 3 years	66.74±18.946	
	Radiological technologist	Less than 1 year	84.03±14.107	4.933**
		Less than 1 ~ 3 years	87.08±11.362	
		More than 3 years	78.50±15.362	
	General item	Less than 1 year	83.28±14.491	5.536**
		Less than 1 ~ 3 years	86.51±10.913	
		More than 3 years	77.79±13.723	
	Total of the behavioral aspect	Less than 1 year	83.03±12.772	5.363**
		Less than 1 ~ 3 years	85.43±9.911	
		More than 3 years	77.31±14.573	

Number of radiological technologists in Charge of PET-CT	Patient	Below 2	93.12±9.611	2.002
		Below 3 ~ 5	88.88±15.806	
		More than 6	92.85±9.024	
	Guardian	Below 2	75.18±17.001	1.342
		Below 3 ~ 5	69.57±18.569	
		More than 6	72.61±19.765	
	Radiological technologist	Below 2	87.02±11.374	2.186
		Below 3 ~ 5	81.91±15.118	
		More than 6	84.87±12.948	
	General item	Below 2	86.90±10.752	6.094**
		Below 3 ~ 5	79.12±13.018	
		More than 6	85.94±14.044	
	Total of the Behavioral aspect	Below 2	85.55±9.462	3.292*
		Below 3 ~ 5	79.97±13.814	
		More than 6	84.07±12.637	

*p<0.05, **p<0.01

3-2-4. Differences in the behavioral aspect of radiation safety management according to general features

There were no significant differences of value through genders, education status, locations of organizations, and establishment bodies of organizations among general features.
But there was significant value difference in marital status item.

Table 6. Differences in the Behavioral Aspect of Radiation Safety Management According to General Features

Characteristics	Item		mean±SD	t or F
Age	Patient	20s	95.63±7.137	4.203*
		30s	91.66±10.810	
		40s	87.96±15.926	
	Guardian	20s	73.56±19.315	0.464
		30s	73.60±17.842	
		40s	70.27±17.825	
	Radiological Technologist	20s	87.29±11.735	1.824
		30s	85.18±13.084	
		40s	81.69±14.148	
	General item	20s	86.17±13.615	5.918**
		30s	86.18±11.299	
		40s	78.29±12.646	
	Total of the behavioral aspect	20s	85.66±11.766	2.817
		30s	84.16±11.100	
		40s	79.67±12.778	

Marriage	Patient	Unmarried	95.30±7.804	3.063**
		Married	89.48±13.311	
	Guardian	Unmarried	74.38±17.629	0.874
		Married	71.74±18.519	
	Radiological Technologist	Unmarried	87.74±12.100	2.220*
		Married	82.99±13.447	
	General item	Unmarried	86.27±12.775	1.621
		Married	82.90±12.454	
	Total of the behavioral aspect	Unmarried	85.92±11.318	2.119*
		Married	81.81±11.952	

*$p<0.05$, **$p<0.01$

3-2-5. Correlation between the environmental and behavioral aspects in radiation safety management and the features of research subjects

The correlation between the environment and the behavior in radiation safety management showed the highest Coefficient value, $r=0.697 (p<0.01)$.

The correlation between the dosimeter-wearing period and the radiation safety management environment showed negative.

The correlation between the self-efficacy and the radiation safety management environment was $r=0.210$ ($p<0.01$), and that between The self-efficacy and the radiation safety management behavior was $r=0.265 (p<0.01)$(Table 7).

Table 7. Correlation Matrix of the Environmental and Behavioral Aspects in Radiation Safety Management and the Features of Research Subjects

	Region	Foundation principal	Wearing period of a personal dosimeter	Number of patients in the daily inspection	Number of education	Self-efficacy	Environmental aspect	Behavioral aspect
Region	1							
Foundation principal	0.135	1						
Wearing period of a personal dosimeter	-0.040	-0.224**	1					
Number of patients in the daily inspection	-0.234**	0.001	-0.131	1				
Number of education	-0.196*	0.053	0.089	0.178*	1			
Self-efficacy	-0.021	0.129	-0.103	0.027	0.098	1		
Environmental aspect	0.056	-0.135	-0.165*	0.023	0.075	0.210**	1	
Behavioral aspect	0.101	-0.033	-0.131	-0.024	0.093	0.265**	0.697**	1

*$p<0.05$, **$p<0.01$

3-2-6. Factors affected on the radiation safety management behavior

The factors that affect radiation safety management behavior were presented as academic achievement(B=2.607, $p<0.05$), safety Management environment for radiological technologists(B=0.138, $p<0.05$), a nd general safety management environment(B=0.488, $p<0.001$).

Through the results, it can be expected that the higher the level of academic achievement in both, safety management environment for radiological Technologists and general safety management environment, the higher the level of radiation safety management behavior.

About 60(59.4)% of the total radiation in the radiation safety management behavior was explained by the regression(Table 8).

Table 8. Factors Affected on the Radiation Safety Management Behavior

Independent Variable	Non-standardized Coefficient		Standardized Coefficient	t	Significance Probability
	B	Standard Error	Beta		
(Constant)	6.712	9.345		0.718	0.474
Age	-1.415	1.595	-0.080	-0.887	0.377
Academic career	2.607	1.147	0.139	2.272*	0.025
Wearing period of a personal dosimeter	0.450	1.242	0.031	0.362	0.718
Number of patients in the daily inspection	-0.643	1.194	-0.034	-0.538	0.591
Number of education on radiation damage protection	0.240	1.923	0.008	0.125	0.901
Self-efficacy	0.079	0.068	0.073	1.166	0.246
Radiation safety management environment for patients	0.109	0.059	0.135	1.858	0.066
Radiation safety management environment for guardian	0.054	0.058	0.075	0.929	0.355
Radiation safety management environment for radiological technologists	0.138	0.062	0.179	2.214*	0.029
Radiation safety management environment for common features	0.488	0.072	0.510	6.762***	0.000
F(p-value) 17.148(0.000)					

R^2=0.594

*$p<0.05$, ***$p<0.001$

Conclusion

As the latency of the radiation exposure to patients and medical staff has increased according to significant increase in the installation and application of PET-CT, it is necessary to secure backing materials to establish the radiation safety plan for the staff working in PET-CT rooms.

Thus, this study attempted to provide improvements through the analysis of factors of environmental, behavior, and personal aspects related to radiation safety management.

It is necessary to primarily enhance the environment for radiological technologists among radiation safety management environments, and Also to primarily enhance the level of behavior for guardians among radiation safety management behaviors.

As the correlation between the environment and the behavior in radiation safety management showed the highest value, $r=0.697$ ($p<0.01$), it is necessary to improve both environmental and behavioral aspects to enhance the overall level of radiation safety management.

As the factors that affect the radiation safety management behavior were presented as the academic achevement(B=2.607, $p<0.05$), the safety management environment for radiological technologists(B=0.138, $p<0.05$), and the general safety management environment (B=0.488, $p<0.001$) in which the explanatory power was 59.4%, it is necessary to improve the primarily radiation safety environment for radiological technologists and the general radiation safety management environment.

In order to reduce the radiation exposure to patients, guardians, and medical staff caused by using PET-CT, a strategy to improve the level of radiation safety management environment is expected to be more effective than other strategies through applying other factors.

Because the environment of radiation safety management showed the highest correlation to the behavior, and affects the behavior as a major factor, it can be expected that if the environmental factors are improved, the behavior level in the radiation safety management of radiological technologists will improve.

As this is the first research on environmental and behavioral aspects of the safety management of PET-CTs, which are on the drastic rise in its installation, there are unstable parts in the presently existing measuring tools.

The generalization of the tools should be in place by using the same tools in further researches.

This research will be considered meaningful in providing backing materials for the PET-CT radiation safety management.